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Optimization of Okra yield under varying agronomic practices

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Abstract
In Africa, the increase in food demand as result populations explode has encouraged dry season farming. One of the important vegetable consumption is okra. In this study, optimization of okra yield in dry season farming using automated sprinkler irrigation system was carried out at Imo State polytechnic demonstration farm between February and April 2021. The soil characteristics shows that it is sandy loamy with initial moisture content 10.5 %. The research was designed as factorial experiment of four levels of tillage depths (0cm, 10cm,20cm and 30cm) known as plots A,B,C,D ; irrigation rates (150ml/s, 200 ml/s, 250 ml/s and 300 ml/s) and five levels of fertilizer application rates (0 kg/ha, 50 kg/ha, 100 kg/ha 150 kg/ha and 200 kg/ha). Whereas, weeks of experiment (1-8) was taken as the fourth factor with eight levels. Analysis was done using SPSS version 13 and excel statistical package. The results of okra vine height, number of leaves and yield of okra as well as their models were generated showing how they were affected by farm practices. There was no significant mean difference (0.05 probability level) in the overall effects of tillage depths unlike irrigation rates, fertilizer application and number of weeks. In this study, highest yield was 101.57 g at 20 cm tillage depth, 250ml/s irrigation rate and 150 kg/ha Fertilizer application. The study was concluded by recommending irrigation rates between 150 ml/s and 200 ml/s which ensured minimal water usage and a significant yield at fertilizer application150 kg/ha and 20 cm tillage depth as the best treatment combination.

Keywords: Okra, Tillage Depth, Irrigation and Fertilizer Application

1. Introduction

Crop production in Nigeria is mostly done in the rainy season essentially for availability of rain water. However, the increase in population inevitably necessitated increase in crop production hence there is need for the introduction of dry season farming to ensure all year-round crop production. Irrigation plays a key role in the provision of sufficient moisture necessary for crop production. Kumar et al., 2016 affirmed that commensurate increase in agricultural productivity was necessary to meet increasing food demands from rising global population. In the dry season farming, water is supplied through irrigation from streams, rivers etc. Irrigation is the process by which water is artificially applied and spread over the land to nourish the plant life so as to give maximum crop output (Sahasrabudhe, 2003). The sprinkler irrigation system is a crop irrigation method similar to rainfall. The system distributes water over the field surface by spraying it into the air and allowing it to fall on the soil similar to that of rain. According to Knox et al., 2012, irrigation globally consumes 70% of fresh water whereas it is as high as 80% in developing countries such as Nigeria with a population of about 200 million people (Hedley et al., 2014).

Apart from the availability of water for irrigation purposes, efficient monitoring of irrigation systems is vital to reduce high human labour, wrong timing and water wastage. According to Wang et al. 2007, optical and infrared photography (IR) images of plants have been used to monitor irrigation. The principle of these devices is to monitor the temperature and humidity at the root zone of crops with an automated system such that it determines when to irrigate and to maintain soil moisture content at a required threshold value sufficiently required to sustain crops (Nemali and Van Lersel, 2006). Lanre et al., 2019, in their study used relevant technologies to increase modern agricultural practices and crop yields, which is critical for long-term sustainability. Automating farm or nursery irrigation allows farmers to apply the right amount of water at the right time, regardless of the availability of labour to turn valves on and off. Idama, and Ekruyota, ,2021 designed and developed an automated irrigation system using internet services by creating a prototype drip irrigation robotic system that operated using internet connections. In addition, farmers using automation equipment are able to reduce runoff from over watering saturated soils, avoid irrigating at the wrong time of day, which will improve crop performance by ensuring adequate water and nutrients when needed. It also helps in time saving, removal of human error in adjusting available soil moisture levels and to maximize their net profits. Irrigation improves maize, wheat and rice yield in Northern part of Nigeria with low seasonal rainfall (Osei, 2009). The aim of the study is to optimize yield of okra in dry season farming using automated sprinkler irrigation system.

2.0 Material and methods

2.1 Study Area and Field Preparation

The experiment was carried out at the Department of Agricultural and Bio-environmental Engineering Experimental farm, Imo State Polytechnic Umuagwo. The site lies between latitude 5^0 18’ 12.60’’N and longitude 6^0 56’ 26.39’E and altitude of 52m. The map of the study area is presented in figure 1, while the soil characteristic of the plot is shown in Table 1.

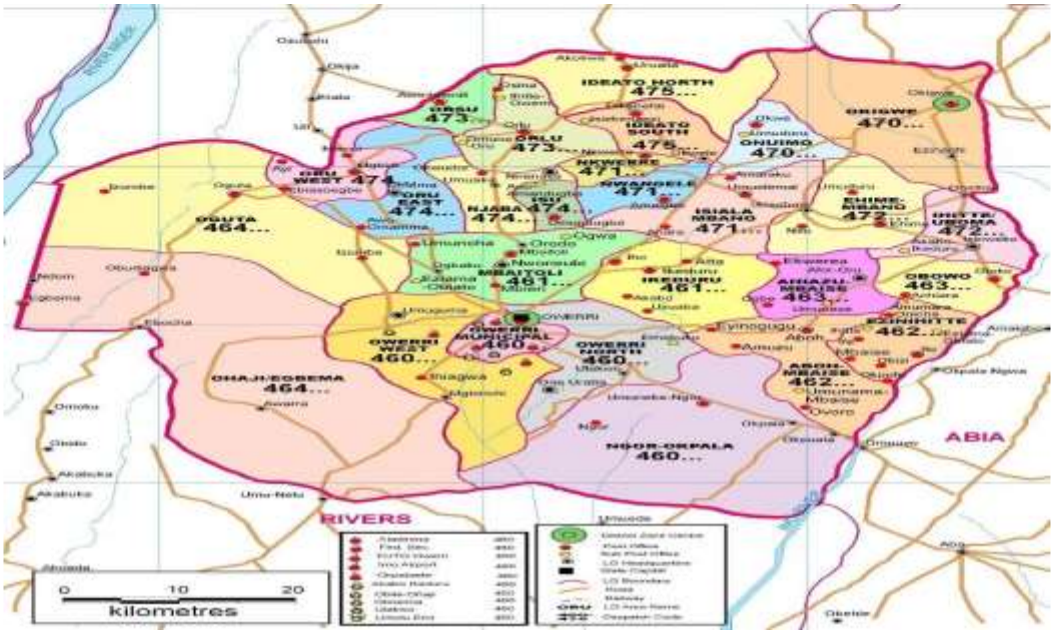


Figure 1: Map of Imo State
(Source: Ikpeama et al, 2017)

2.2 Experimental Design

The experiment was designed as a factorial experiment. The factors considered were tillage depth, irrigation rates, fertilizer application and number of weeks on the vine length, number of leaves and yield of okra after the 8th week.
The field was first prepared by dividing it into four major plots namely A, B, C and D of 20m x 15m each. Four tillage depths of 0, 10, 20 and 30cm were used for plots A, B, C and D respectively. Each plot was irrigated at four levels of irrigation rates of 150, 200, 250 and 300ml/s, five fertilizer applications rates of 0, 50, 100, 150 and 200g and eight weeks period of okra to maturity. The experiment was replicated four times. Therefore, the numbers of experiment units from week 1 to 8 of the experiment are: 4x4x5x8x4 = 1,280 units. The experimental matrix shows the treatment combinations for only week one of the experiment.

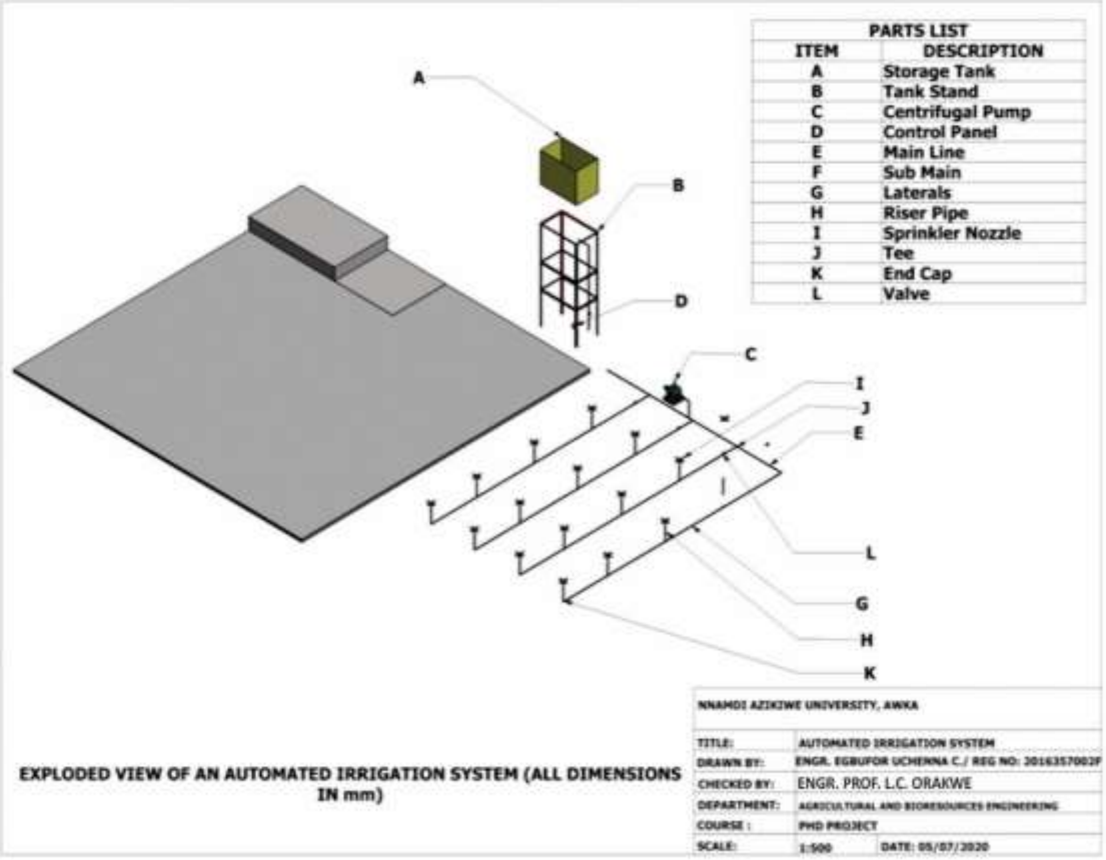
2.3 Statistical Analysis

The analysis was performed using SPSS version 13 and Excel Software packages. The analysis of variance and the significant effects at 5% probability level for each factor as well as the interactions on the vine height and number of leaves at the end of the 8th week were analyzed. The raw data obtained from the field were first formatted in Excel before being transferred to SPSS for analyses. Regression models for vine height and number of leaves were generated from the packages.

Table 1:
Soil characteristic

Soil Properties	Results
Moisture content	10.5%
Bulk density	1.53g/cm^3
Porosity	41.05%
Particle density	2.62g/cm^3
Particle size distribution	Uniformity coefficient (CU) =192, Coefficient of graduation (Cc) = 0.81, Soil fractionation: 16% clay, 22% silt and 62% sand
Consumption use (Cu)	4.25mm/day
Evapotranspiration (ETp)	4.9mm/day
Soil type	Sandy loam

The exploded view of the experimental layout is shown in Figure 2.



PARTS LIST

ITEM	DESCRIPTION
A	Storage Tank
B	Tank Stand
C	Centrifugal Pump
D	Control Panel
E	Main Line
F	Sub Main
G	Laterals
H	Riser Pipe
I	Sprinkler Nozzle
J	Tee
K	End Cap
L	Valve

NNAMDI AZIKIWE UNIVERSITY, AWKA

TITLE:	AUTOMATED IRRIGATION SYSTEM	
DRAWN BY:	ENGR. EGBUFOR UCHENNA C./ REG NO: 2016357002F	
CHECKED BY:	ENGR. PROF. L.C. ORAKWE	
DEPARTMENT:	AGRICULTURAL AND BIORESOURCES ENGINEERING	
COURSE :	PHD PROJECT	
SCALE:	1:500	DATE: 05/07/2020

Figure 2: Exploded view of experiment layout.

3.0 Results and Discussions

The result of the average vine height, number of leaves and yield at the end of the 8th week are presented and discussed below.

(a) Vine length at end of the 8th week (cumulative effect)

The analysis of variance, test between subject means and the interaction effects for vine height.

Table 2: The analysis of variance for Vine Length (cm)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	641224.582[a]	591	1084.982	10.331	.000	.756
Intercept	1216316.417	1	1216316.417	11581.108	.000	.855
Depth	142.835	3	47.612	.453	.715	.001
Irrigation	1869.903	3	623.301	5.935	.001	.009
Depth * Irrigation	1467.695	9	163.077	1.553	.124	.007
Week	418923.461	7	59846.209	569.823	.000	.670
Depth * Week	3838.807	21	182.800	1.741	.020	.018
Irrigation * Week	3884.351	21	184.969	1.761	.018	.018
Depth * Irrigation * Week	8932.856	63	141.791	1.350	.036	.041
Fertilizer	10869.401	4	2717.350	25.873	.000	.050
Depth * Fertilizer	2157.763	12	179.814	1.712	.058	.010
Irrigation * Fertilizer	2762.058	12	230.172	2.192	.010	.013
Week * Fertilizer	19592.837	28	699.744	6.663	.000	.087
Depth * Irrigation * Week * Fertilizer	57411.853	408	140.715	1.340	.000	.217
Error	206690.989	1968	105.026			
Total	2350636.927	2560				
Corrected Total	847915.571	2559				

a. R Squared = 0.756 (Adjusted R Squared =0 .683)

From table 2, the corrected model is significant capturing up to 75.6% (R square = 0.756) variation of the all factors, the Adjusted R-square (0.683) is also reasonably close to the R Square. The corrected model equation is shown below.

$$Y_1 = 45.881 + 0.126x_{11} + 0.456x_{12} + 0.696x_{13} + 1.281x_{21} - 0.390x_{22} + 2.302x_{23} - 1.383x_{31} + 0.597x_{32} + 1.482x_{33} + 5.280x_{34} - 43.768x_{41} - 38.270x_{42} - 33.103x_{43} - 28.294x_{44} - 24.189x_{45} - 16.563x_{46} - 6.900x_{47}$$

Where $Y_1 = Vine\ length\ during\ week\ 1\ to\ week\ 8$

$x_{11} = tillage\ depth\ at\ 0cm$

$x_{12} = tillage\ depthat\ 10cm$

$x_{13} = illage\ depth\ at\ 20cm$

$x_{21} = Irrigation\ at\ 150ml/s$
$x_{22} = Irrigation\ at\ 2000ml/s$
$x_{23} = Irrigation\ at\ 250ml/s$
$x_{31} = Fertilizer\ at\ 0kg/ha$
$x_{32} = Fertilizer\ at\ 50kg/ha$
$x_{33} = Fertilizer\ at\ 100kg/ha$
$x_{34} = Fertilizer\ at\ 150kg/ha.$

$x_{41} = Week\ 1$

$x_{42} = Week\ 2$
$x_{43} = Week\ 3$
$x_{44} = Week\ 4$
$x_{45} = Week\ 5$
$x_{46} = Week\ 6$

$x_{47} = Week\ 7$
$x_{48} = Week\ 8$

From Table 2, the overall effect of tillage depth at the end of experiment was not significant. By implication, there are no advantages any of the tillage depths have over another in terms of influence to increase in vine length. Though the cumulative effect of irrigation rates at the end of the experiment is significant, it contributes only about 0.9% to overall change in vine length. However, test of multiple comparison performed on the levels of irrigation rates indicated significant mean difference between only 150ml/s and 200ml/s, whereas above 200ml/s there was no significant difference. It implies that in terms of influence to increase in vine length, irrigating okra farm at 150 ml/s and 200ml/s irrigation rates were most adequate and as well as reduce water wastage. The cumulative effect of fertilizer application rates is significant and contributed 5% to the overall changes observed in the vine length. But test of multiple comparison among the rates shows only the effect of 150kg/ha fertilizer rates had comparative advantaged in terms of influence to increase in vine length. By implication, 150ml/s is the most active fertilizer application rate that affected vine length hence application from 200kg/ha and above amounts to waste of fertilizer. The changes in number of weeks (1-8weeks) are significant and contributed 67% to the overall change in vine length. The multiple comparison of weeks indicated that the effects from week 1 to week 8 are significantly different. By implication, none of the weeks from 1 to 8 had the same in effect. Therefore, at every week, changes in vine length were meaningfully different from the previous weeks.

The influence of interactions between tillage, irrigation rate , tillage depth and fertilizer application were non significant whereas between weeks and tillage depths, irrigation and fertilizer application rates are all significant and contributed 1.8%, 1.8% and 8.7% respectively to overall changes observed in vine length. Graphical representation of the influence of the interactions among weeks with tillage depth, irrigation rate and fertilizer application rates are shown in Figures 1 to 4 below. The figures show a general increase in influence across weeks 1 to 8 which support the observation on influence of weeks from 1 to 8th. The implication is that across weeks, all the factors contributed meaningful changes to vine length although individually, their cumulative effect may not be significant such as tillage depth.

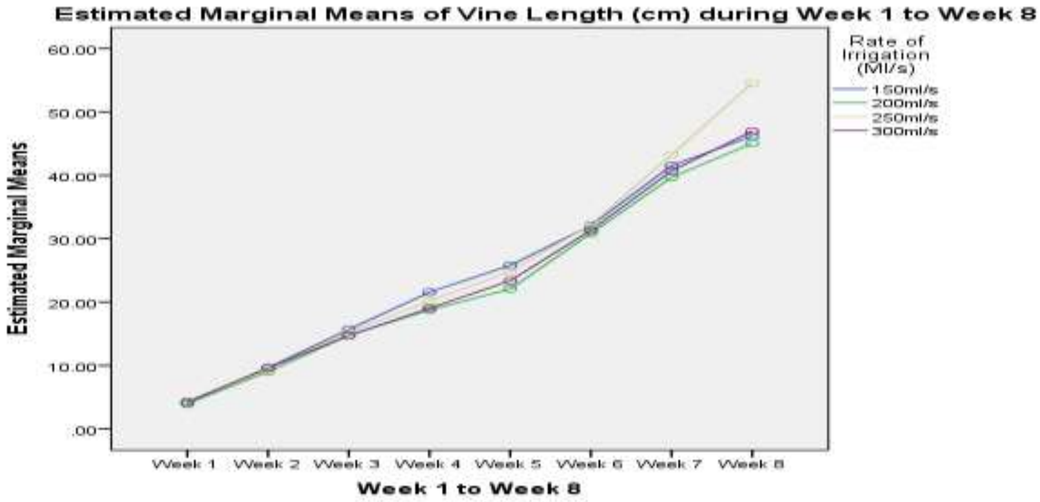


Figure 1: Cumulative effect of rate of irrigation on vine length across weeks 1 to 8

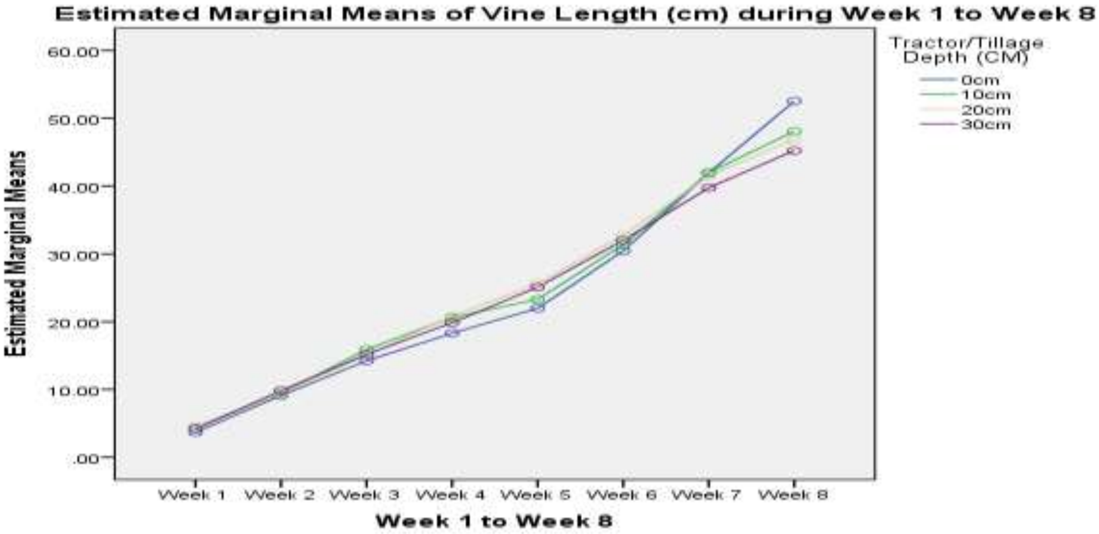


Figure 2: Cumulative effect of tillage depth on vine length across weeks 1 to 8

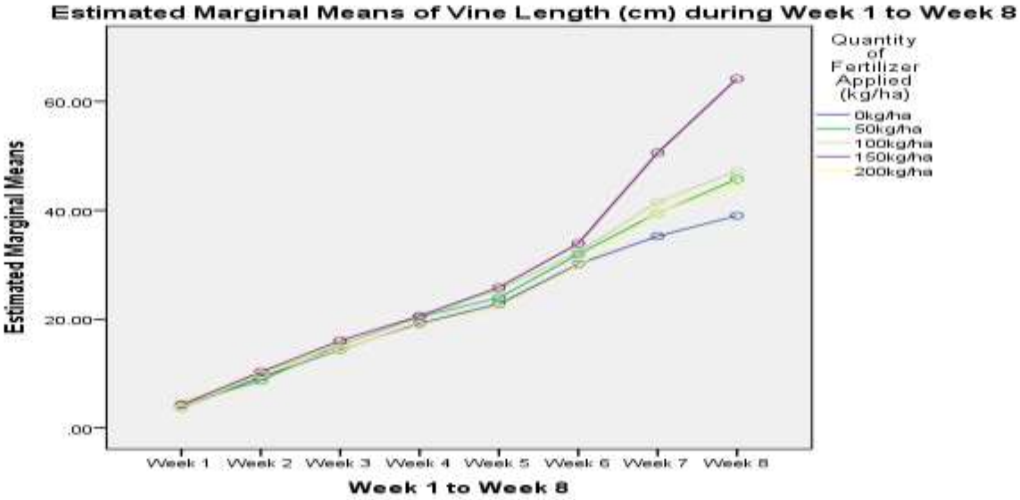


Figure 3: Cumulative effect of fertilizer application on vine length across weeks 1 to 8

b. Number of leaves week 1- 8 (cumulative effect)

The ANOVA, test of subject means and the effects on number of leaves are shown in Table 3 and the corrected model equation of the cumulative effect is significant and shown below

$$Y_2 = 20.146 - 0.240x_{11} + 0.59x_{12} + 0.213x_{13} + 0.468x_{21} - 0.151x_{22} + 0.682x_{23} - 0.419x_{31} + 0.414x_{32} + 0.785x_{33} + 1.982x_{34} - 17.047x_{41} - 15.619x_{42} - 13.200x_{43} - 11.259x_{44} - 9.745x_{45} - 5.463x_{46} - 0.631x_{47}$$

Where $Y = Number\ of\ Leaves\ during\ week\ 1\ to\ week\ 8$

$$x_{11} = Depth\ at\ 0cm\ level$$
$$x_{12} = Depth\ at\ 10cm\ level$$
$$x_{13} = Depth\ at\ 20cm\ level$$

$x_{21} = Irrigation\ at\ 150ml/s$
$x_{22} = Irrigation\ at\ 2000ml/s$
$x_{23} = Irrigation\ at\ 250ml/s$
$x_{31} = Feretilizer\ at\ 0kg/ha$
$x_{32} = Feretilizer\ at\ 50kg/ha$
$x_{33} = Feretilizer\ at\ 100kg/ha$
$x_{34} = Feretilizer\ at\ 150kg/ha.$
$x_{41} = Week\ 1,$
$x_{42} = Week\ 2$
$x_{43} = Week\ 3$
$x_{44} = Week\ 4$
$x_{45} = Week\ 5$
$x_{46} = Week\ 6$
$x_{47} = Week\ 7$
$x_{48} = Week\ 8.$

Table 3: ANOVA, test of subject means on Number of leaves during Week 1 to Week 8 (cumulative effect)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	103009.463[a]	579	177.909	69.361	.000	.954
Intercept	274680.264	1	274680.264	107088.201	.000	.982
Depth	52.101	3	17.367	6.771	.000	.010
Irrigation	137.086	3	45.695	17.815	.000	.027
Depth * Irrigation	73.732	9	8.192	3.194	.001	.015
Week	76533.968	7	10933.424	4262.559	.000	.939
Depth * Week	268.289	21	12.776	4.981	.000	.051
Irrigation * Week	172.215	21	8.201	3.197	.000	.034
Depth * Irrigation * Week	463.618	63	7.359	2.869	.000	.086
Fertilizer	1204.223	4	301.056	117.371	.000	.195
Depth * Fertilizer	285.893	12	23.824	9.288	.000	.055
Irrigation * Fertilizer	205.590	12	17.133	6.679	.000	.040
Week * Fertilizer	1765.606	28	63.057	24.584	.000	.263
Depth * Irrigation * Week * Fertilizer	2539.656	396	6.413	2.500	.000	.339
Error	4955.563	1932	2.565			
Total	460062.000	2512				
Corrected Total	107965.025	2511				

a. R Squared = 0.954 (Adjusted R Squared = 0.940)

From Table 3 above, the corrected model is significant with R square of 0.954 and adjusted R square 0.940. All the factors and the interactions are significant. It means that changes observed in number of leaves from week 1 to 8 were brought about by cumulative effect of all factors and interactions. Weeks had the highest contribution of 93.9% to increase in number of leaves whereas tillage depth was the least with 0.1%. The cumulative estimated marginal means of number of leaves during week 1 to 8 shown indicate that the influence of the factors on number of leaves increased from week 1 to 8 respectively. The estimated marginal means of number of leaves during week 1 to 8 for irrigation rates, tillage depth and fertilizer application are shown in Figures 4 to 6. The effects of the factors on number of leaves increased across weeks 1 to 8.

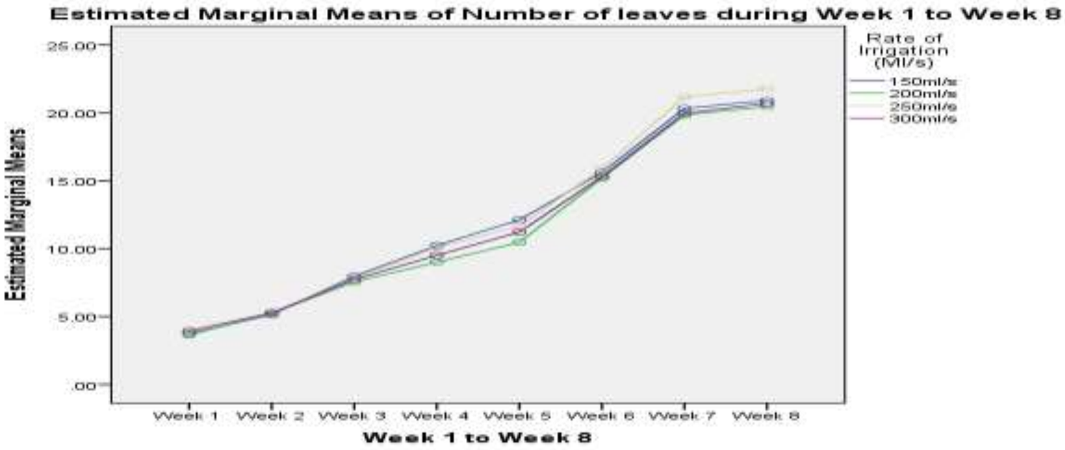


Figure 4: The cumulative effect of the interaction between weeks and irrigation rate on number of leaves

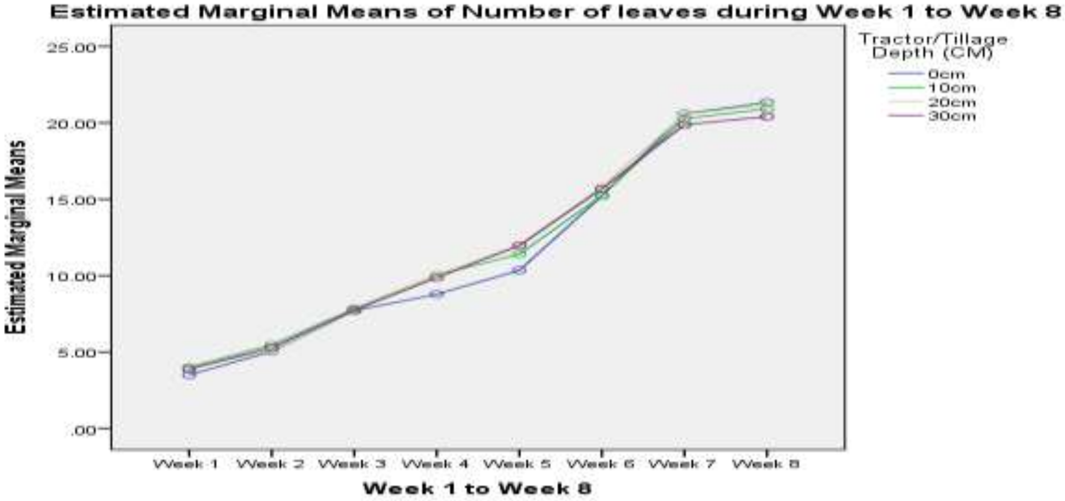


Figure 5: The cumulative effect of the interaction between weeks and tillage depth on number of leaves

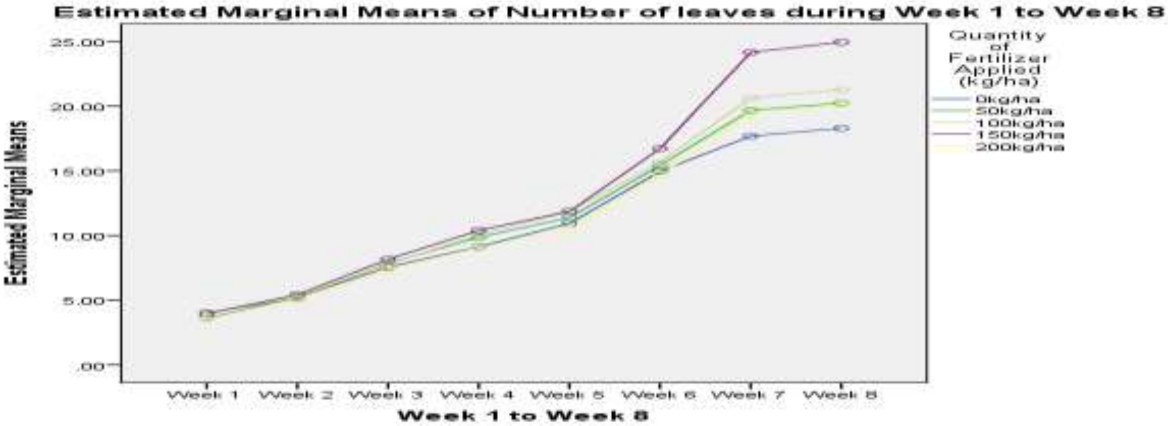


Figure 6: The cumulative effect of the interaction between weeks and fertilizer application rate on number of leaves

c. Okra Yield

The result of the Okra yield presented in Figures 7 to 10 for 0cm, 10cm, 20cm and 30cm respectively. The highest yield at 0cm tillage depth was 79.3g in plot of irrigation 250ml/s, fertilizer application 150kg/ha.

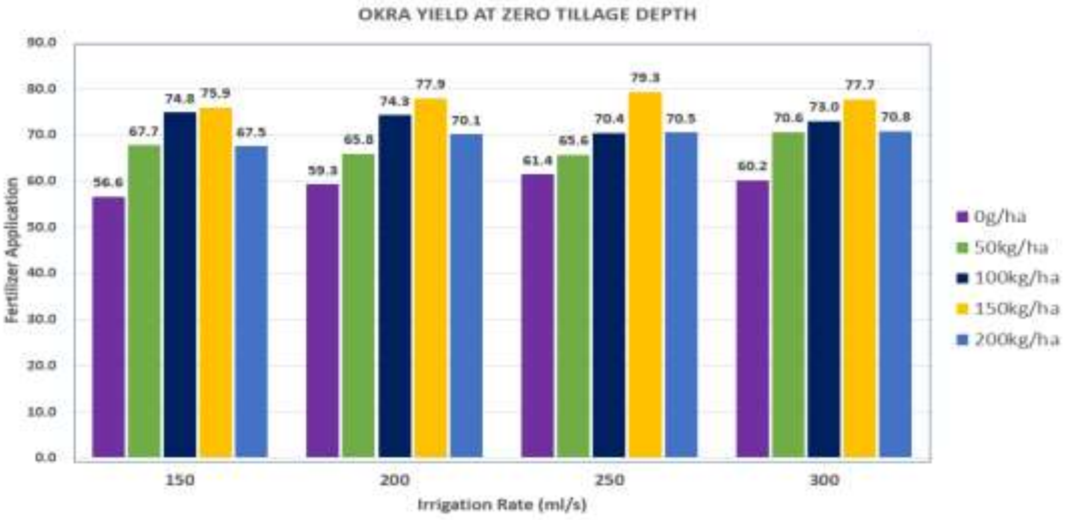


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Figure 7: Okra yield at 0cm tillage depth.

Yield in plot 10cm tillage depth (figure 8) was 89.6g at250ml/s irrigation rate and 150kg/ha fertilizer application rate.

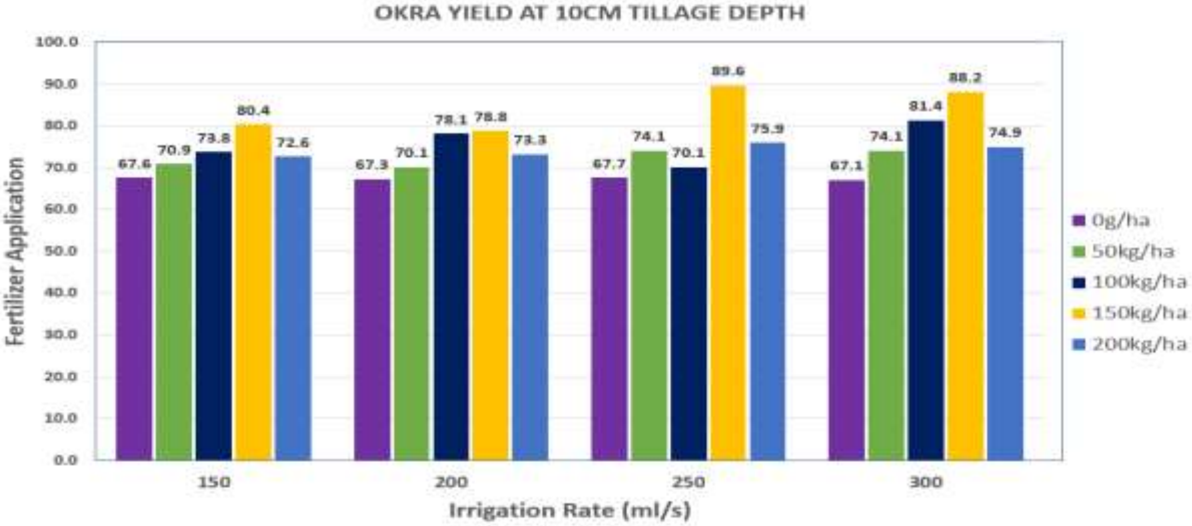

Figure 8: Okra yield at 20cm Tillage Depth

The highest average yield of the experiment was 101.57g from plot of20cmtillage depth, 250ml/s irrigation rate and 150kg/ha of Fertilizer application..

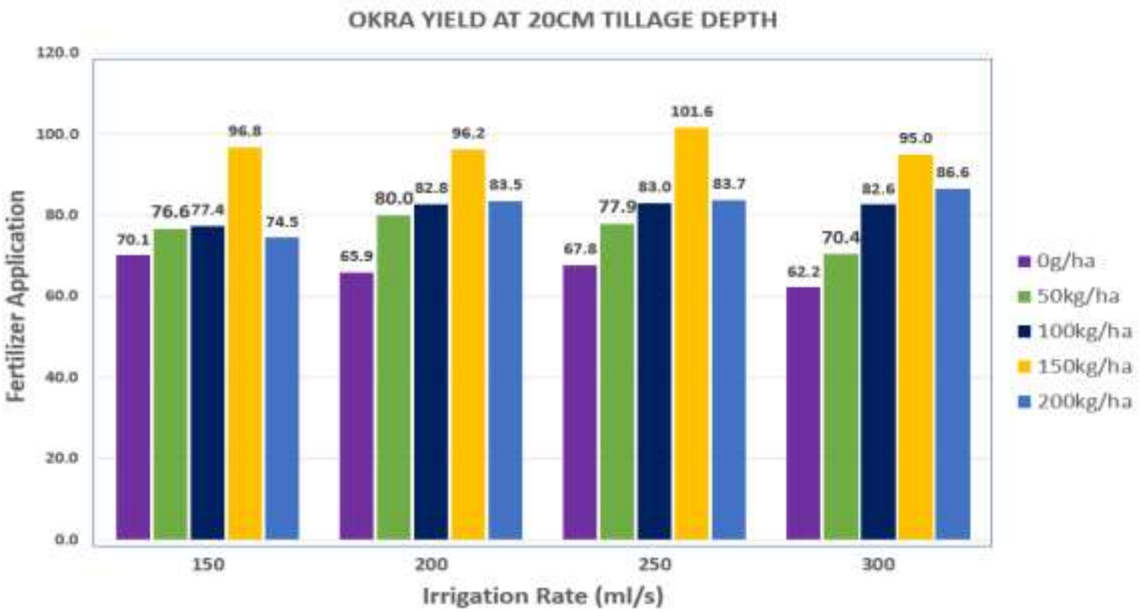

Figure 9: Okra yield at 20cm Tillage Depth

The second in terms of yield in the experiment was 97.35g at 30cm tillage depth with 150ml/s of Irrigation rate and 150kg/ha of Fertilizer application.

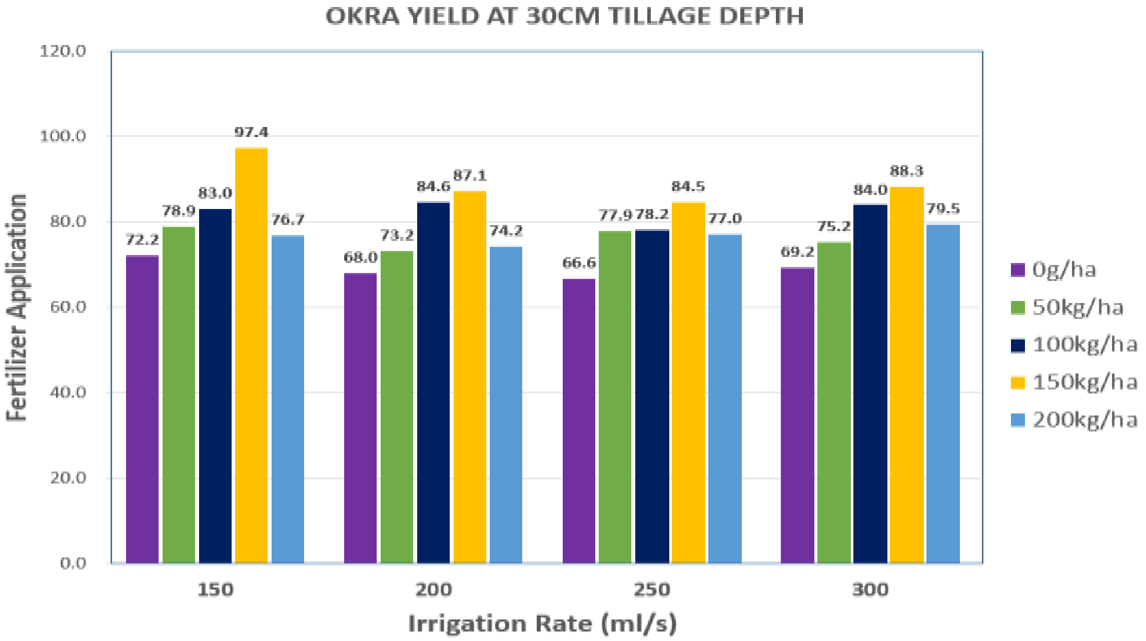

Figure 10: Okra yield at 30cm Tillage Depth

4.0. Conclusion

This study shows that the yield of okra was also affected by farm practice. In a land of sandy-loam properties, the effect of irrigation rate, fertilizer application rate and number of weeks are significant hence should be considered for okra farming during dry season farming. From the study, there are no significant advantage tillage depths have over another except to hold firmly okra root to the ground for a sprinkler irrigated farm. Therefore for a good okra yield in a sandy-loamy soil, tillage depth should not exceed 20cm. However at any depth of tillage, the irrigation rates between 150ml/s and 200ml/s ensure minimal water usage and a significant yield but at fertilizer application of not less than 150kg/ha. Fertilizer application above 150kg/ha amounts to waste. In this study, highest yield was 101.57g at 20cm tillage depth, 250ml/s irrigation rate and 150kg/ha Fertilizer application.

5.0 Recommendation

The effect of irrigation rate and fertilizer application rate should be considered for okra farming during dry season farming.

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